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THE EFFECT OF MANUAL LABOR AND PERSPIRATION ON BLOOD AND TISSUE

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THE EFFECT OF MANUAL LABOR AND PERSPIRATION ON BLOOD AND TISSUE

This paper provides information on changes in the composition of blood and tissue as a result of strenuous muscular activity, hikes, etc. Tests were carried out on dogs, rabbits, small donkeys and on human beings to ascertain water losses in the body, salt losses, and their effect on the body metabolism, in particular the blood and tissue. Tests were carried out on humans during a mountain climb in Italy under various conditions of weather, exertion, food intake and perspiration. Under conditions of salt deficiency the body weight was measured prior to departure, upon arrival, and on the following two mornings and the third day. Measurements were made of various factors before and after the trip (albumen in %, serum viscosity, hemoglobin count, body weight, body loss). The authors differentiate three types of water which they refer to as concentration water, reduction water and destruction water and discuss the properties of each. Determinations were made to ascertain the water depots (reservoirs) of the body, such as the muscles. They conclude that water and salt are only temporarily taken from the blood during manual labor and subsequent perspiration and that salt intake is necessary to bring about full replacement of water lost through perspiration.

The manner in which the organism is able to maintain uniformly the composition of its blood under the most varied conditions is apparently very complicated and manifold. An understanding of the limits within which the composition of the blood remains unaltered or of the changes in its composition, for example after loss of water or salt, are of equal importance to the physiology and pathology of the water and mineral metabolism. Cohnheim, Tobler, Weber and Kreglinger[1] found that a considerable loss of sodium chloride is also linked with water loss due to perspiring, that some of the phenomena occurring after long marches are related to this loss in sodium chloride, and,

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[1] Cohnheim and Kreglinger, Zeitschr. f. physiol. Chem. 1909, Vol. 63- Cohnheim, Kreglinger, Tobler, Weber, ibid. 1912, Vol. 78.

/Numbers in the margin indicate pagination in the original foreign text.

above all, that in the case of a great deficiency of chlorine in the body, in the opinion of Tobler[2], the lost water cannot be retained by the organism, even if a large quantity of water is taken, if the body does not receive a corresponding amount of sodium chloride at the same time. This conclusion was reached from the behavior of the body weight after heavy perspiration. The perspiration resulted in a loss in weight. If the necessary amount of salt /188 is included in the diet, then the loss in weight is quickly made up for, usually in less than 24 hours. If salt is lacking in the diet then the abundant water intake which follows the perspiring only leads to abundant urine excretion. The body weight, however, only increased slowly or not at all and then rose abruptly to its former value when the loss in sodium chloride in perspiring was replaced by salt intake. The following amounts in grams were observed in the salt intake:

	Cohnheim	Kreglinger	Tobler	Weber
Prior to departure	84,400	78,800	64,900	64,500
Upon arrival	81,200	77,150	62,250	62,500
Following morning	84,100	78,650	64,600	63,500
Morning after that	85,200	79,000	65,000	64,150

During salt deficiency the body weight behaved as follows:

	Cohnheim		Kreglinger		Tobler		Weber
Prior to departure	84,150	82,900	77,400	79,500	64,050	64,650	63,650
Upon arrival	83,100	79,550	74,450	78,450	61,450	64,000	62,900
Following morning	82,600	80,975	74,450	78,500	62,800	64,000	63,200
Morning after that		81,600	74,750		63,400		63,150
Third Day			75,100				

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[2] Tobler, Archiv f. exp. Path. u. Pharmak. 1910, Vol. 62

In this case, too, we determined the body weight in a salt-free diet and once more used, as in the previous case, the ascent (trip) from the Mosso Institute to the Margherita hut. The difference in altitude was 1,660 meters, the altitude which was to be climbed was somewhat higher since the path continued upwards for a stretch. The trip first went over a path most of which was lightly packed, only occasionally, harder packed snow. The trip lasted 5 to 7 hours depending on the snow and the training. The fatigue became noticeably greater somewhere after Lysjoch (the Lys mountain path) (4200 meters), as one is accustomed to walking over a snow field.

	Kestner	Weber	Schlagintweit	Mrs. K.
Prior to departure	84,300	59,900	58,400	68,400
Upon arriving	82,000	57,300	56,000	67,100
Following morning	82,100	57,100	56,000	67,550

In this case of a salt-free diet, therefore, the lost water and the water taken cannot be replaced, or else, is insufficiently replaced. The chlorine reserves of a human body which has been subjected to loss of perspiration are indeed very great, but the organism is truly in a state of chlorine deficiency/189 after losses in perspiration because of the considerable chlorine retention. This was observed by Cornheim and Kreglinger and Cohnheim, Kreglinger, Tobler and Weber during the days after the losses by perspiration. They determined the chlorine content in the diet and in the urine and found:

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	Intake g. NaCl	Secretion g. NaCl	Retention g. NaCl	Loss in Weight in grams
Cohnheim 1909	18.5	10.4	8.1	4000
Cohnheim 1911	24.4	17.3	7.1	3600
Kreglinger 1909	21.5	10.9	10.6	3900
Kreglinger 1911	24.4	14.3	10.1	2250
Kreglinger II, 1909	18.5	14.2	14.3	5800
Kestner, 1909	18.5	8.7	9.8	4100
Tobler, 1911	22.9	16.4	6.5	2200
Weber, 1911	17.7	12.3	5.4	2600

The last column gives the loss in weight which resulted in the body before and after the food intake and the loss of urine and excrements. The loss is made up primarily of water which left the body to a large extent in the form of perspiration and to a much lesser extent as a result of expiring air.

The figures branch off with respect to the sodium chloride content. Recently, Kittsteiner[1] assumed that the concentration increases considerably in the case of heavy excretion and can finally attain 0.7% NaCl. He believes that the body makes an attempt not to give up any water without at the same time removing salt, but it must also be kept in mind that still other glandular excretions also approach the structure of the serum during intense activity. The figures observed by Durig, Neuberg and Zuntz[2], and those observed in perspiration processes are lower than those computed from our sodium chloride retentions. But our absolute values are also much greater.

Water and salt are then naturally taken away from the blood. It was to be expected that the primary loss in the blood would be immediately compensated for by release from the tissues; that it would finally result in a

[1] C. Kittsteiner, Archiv. f. Hyg. Vol. 57, P. 176.
[2] A. Durig, Neuberg, N. Zuntz Biochem. Zeitschr. 1916, Vol. 72, P. 274.

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deficiency in the water and salt reserves of the tissues[1]. It was not determined whether the loss in the blood could be completely restored or whether, as could be assumed from other experiences (Behavior of the blood after venesections), an increased flowing in of salt solution would take place from the tissues into the blood so that a dilution of the blood would come about. The latter supposition was supported by observations made by Cohnheim and Kreglinger and Laquer[2] who had established a regular loss in hemoglobins (Hb) after strenuous marches, Cohnheim and Kreglinger presented the following table in which the hemoglobin values were determined with the Haldane hemoglobinometer (carbon monoxide hemoglobin):

Cohnheim		Kreglinger I		Kreglinger II		Mrs. K.	
Rest	Activity	Rest	Activity	Rest	Activity	Rest	Activity
110	101	104	95	97	101	100	93
116	102	98	93	102	98	102	99
110	97	90	88			112	102
102	99	90	90				
106	100						

Laquer provided the following values (erythrocytes with the Burker counting chamber; hemoglobin with the Autenrieth-Konigsberger colorimeter).

Date	Laquer	Hb	Erythr.	Date	Laquer	Hb.	Erythr.
Aug. 14	Rest	88	5,800,000	Aug. 21	Rest	90	5,530,000
Aug. 15	Activity	83	5,480,000	Aug. 21	Activity	84	5,430,000
Aug. 16	Rest	87	5,670,000	Aug. 22	Rest	91	5,700,000
				Aug. 22	Activity	87	5,230,000

Date	Laquer	Hb	Erythr.
Aug. 27	Rest	93	6,160,000
Aug. 28	Activity	89	5,630,000
Aug. 29	Rest	91	6,060,000

[1]Schwankenbecher and Spitta, Arch. f. exper. Path. u. Pharmak. 1907, Vol. 56, P, 284. E. Berry, Biochem. Zeitschr. 1916, Vol. 72, P. 285.
[2]Mrs. Laquer, Deutsch Arch. f. klin. Med. 1913, Vol. 110, P. 202.

In this connection we can add still another series of figures from the
current year. The analysis was carried out by Weber with the Autenrieth and
Konigsberger colorimeter. The figures have been converted to Sahli (compare
the papers by Laquer and Weber).

Weber		Schagintwelt	
Rest	Work	Rest	Work
81	79	86	83
77	74		
84	81,78	D.J.	
78	75	73	71
75	73		

This means, therefore, that with the rapid decrease and equally rapid sub-
sequent increase in the number of blood corpuscles the change can only relate
to the plasma, an increase in the blood plasma caused by manual labor with
perspiration. The question is now asked whether the amount of plasma merely
increases or whether the composition of the plasma is also somewhat altered.
A change in the albumen or salt content of this liquid was, of course, essential
for the viscosity and hence for the circulation rates or for the osmotic rates.
The plan of the new investigation was, therefore, to determine the following
elements in the blood before and after strenuous marches: hemoglobin or num-
ber of red corpuscles and, in addition, the albumen content and the viscosity
of the serum as a standard for the concentration or dilution of the serum by
an isotonic salt solution, whereas at the same time the total water loss of
the body was determined by weighings. We then carried out an experiment on
human blood which was extracted from the tip of the finger. Venous blood was
not considered since a congestion can cause changes in the pertinent condi-
tions. We could not decide upon obtaining arterial blood from human beings,
but we extended our tests to the arterial blood of animals. Small animals,

such as rabbits, cannot be used for experiments of this type. Abderhalden show-
ed that in the case of small animals there occurs, under the effect of altitude,
a significant decrease in the amount of plasma which, in mountainous climates,/192
brings about a change in the very conditions that we wanted to test in the ani-
mals. Cohnheim and Kreglinger have, however, already pointed out that no con-
clusions should be made for human beings from rabbits and other small animals.
The rabbit does not evaporate any water for purposes of heat regulation and, as
a result, only has insignificant water reserves from which water losses can be
replenished. The rabbit is defenseless against the drying effect of the moun-
tain climate as is precisely shown by Abderhalden's figures[1]. The dog has a-
bundant water reserves. Magnus[2] and Engels[3] have already established the ex-
istence of these reserves. Dogs do not perspire and consequently their chlo-
rine reserves are relatively small. Drainage of the gastric juices during a
meal suffices to cause chlorine hunger[4]. We did not have the equipment to test
horses and mules. Consequently we used small Sardinian donkeys, the smallest
perspiring animals. These animals proved to be extremely capable and patient
test animals and we can also highly recommend them for other physiological in-
vestigations. We made the same analysis in their arterial blood as in the case
of the blood from the finger tip of a human being. In addition, we also de-
termined the freezing-point reduction of the serum in order to obtain a basis
for eventual changes in the salt content. Then, for purposes of controlling

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[1]E. Abderhalden, Zeitschr. f. Biol. 1902, Vol. 43.
[2]R. Magnus, Arch. f. exper. Path. u. Pharmak. 1900, Vol. 44, P. 48 and 396,
  1901 V. 45, P. 210
[3]W. Engels, ibid. 1904, Vol 51, P/ 346.
[4]L. Tobler, Zeitschr. f. physiol. Chem. 1905, Vol. 45, P. 185- R. Rosemann,
  Pflugers Arch. 1911 Vol. 142 P. 208- V. Batke, ibid. 1917, Vol. 168, P. 82.

the other methods of analysis in these animals from which sufficient amounts of

blood were available, we also directly analyzed the albumen content and the

chlorine content of the serum, and, finally, we measured the water content and

the chlorine content in the tissues in order to determine from the excrements

which tissues would replace the losses of water and salt in the blood.

Whereas Cohnheim and Kreglinger found a regular decrease in the hemoglo- /193

bin content after strenuous marches, according to Zuntz and Schumberg[1] the num-

ber of red blood corpuscles after long marches increased in cmm and Willebrand[2]

and Kluge[3] also observed, after physical exertions of short duration, an in-

crease in erythrocytes. Bohme[4] noticed, after strenuous manual labor of very

short duration, a regular considerable increase of the albumen content deter-

mined refractometrically in the serum and at the same time an increase in the

hemoglobin content.

These conditions were once more investigated for mountain situations where

an increased water loss and, consequently, particularly evident decreases were to

be expected because of the greater water dilution. It was to be expected that,

owing to the lower barometric pressure and the therefore easier water excretion,

in the mountains the water excretion would be greater than on flat land, at

least as regards the water loss through the lungs which is a purely physical

phenomenon.

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[1]Zuntz and Schumburg, Physiol. d. Marsches. Berlin 1901.
[2]Willebrandt, Blutveranderungen durch Muskerlarbeit (Blood changes during Manu-
al Labor). Skand. Arch. f. Physiol. Vol. 14.
[3]Kluge, Ueber Veranderungen der Blutzusammensetzung bei korperlichen Anstren-
gungen in In. Diss. (Changes in blood composition during manual labor) Wurz-
burg 1904.
[4]Bohme, Deutsch, Arch. f. klin. Med. 1911. Vol. 103, Verh. d. Kongr. f. inn. Med.
1910, Vol. 27.

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Since, however, in recent times it was discovered that[5] even this water loss through the lungs could change, it was desirable to determine the amount of water loss. We did this by weighing ourselves in the evenings and in the mornings. The weight loss as a result of urine excretion and eventual water intake corresponds to a smaller extent to the burning processes and other transformations in the body and to a greater extent corresponds to the water excretion through the lungs and perhaps the skin. Perspiration did not occur with the night temperature of the Col d'Olen and the Margherita hut. For comparison purposes, nights without prespiration were selected in the flat lands. We give the figures with the addition of the numerous determinations made by Cohnheim, /194 Kregliner, Tobler, Weber in 1909 and 1911.

Flat lands.

Cohnheim	Kreglinger.	Tobler
360, 211, 300, 243, 312, 350, 243, 295.	320, 150, 300.	150-300.

Average of all figures: 250-280.

Col d'Olen

Cohnheim	Kreglinger	Tobler
330, 510, 100, 340, 400, 0, 585.	650, 350, 550.	150, 750.
O. Weber 300, 400.	Kreglinger II. 550	Mrs. K. 200, 300.
Gross 300.	Schlagintweit 380	Laquer 350
H. Weber 390		Mrs. K. 435

Average of all figures: 420.

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[5] A. Lowy and H. Gerhartz. Pfulugers Arch. 1913. Vol. 151, P. 231, - G. Galeotti, Biochem. Zeitschr. 1912, Vol. 46. P. 173.

	Margherita Hut	
Cohnheim.	Kreglinger I.	Kreglinger II.
350, 225, 150,	200, 600, 500,	0, 100, 350.
370, 340, 350.	400, 250, 300.	

Tobler	O. Weber
400, 300, 250.	235, 350, 300.

Some of the mountain figures are very low, in part (Cohnheim and Kregling-
er II) no decrease whatsoever was observed. This was preceded by exhausting
efforts and the water loss was compensated for by hydrogen intake for the pur-
pose of forming glycogen. This phenomenon, which lowered all of the figures
for the Margherita hut tests, was then reported on by Dr. Eckert in another con-
nection. Excluding these exceptions, the figures indicated that the weight loss
at night is greater in the mountains than on flat land and, since the gas change
in the mountains does not completely suffice for explaining these differences,
the water loss in the body must be greater in the mountains. These figures are,
however, very small when compared to perspiration losses.

The moment greater perspiration secretion supervenes, there are no consider-
able differences between flat lands and mountain lands. The amount of work, /195
temperature and wind are more important. The figures presented by Cohnheim and
Kreglinger and C., Kreglinger, Tobler and Weber, however, refer to the amount
of water loss of the body in mountain climbing. Determinations were made of
the actual weight losses, the intake of food and liquid, and the excretion
through urine and excrements; thus the total body loss. We have also made
such observations in this case and are including them with the earlier observa-
tions. The figures between the parentheses give the computed total body loss.

	C.	K.	Kr.1	Kr.2	T.	O.W.	G.	L.	Sch.	H. W.
I. Ascent from the Laboratory to the Margherita Hut.										
Sun, no wind	3800 (4000)	3800 (4100)	3700 (3900)	5600 (5800)						
Sun, windy	3200 (3620)		1650 (2250)		1650 (2190)	2000 (2600)			2400 (2050)	2600 (2300)
Haze, wind	2650 (3450)						1900 (2590)	2400 (3150)	2550 (2300)	2300 (2520)
II. Climbing trips to the Punta Straling.										
Sun	3350 (5800)		3000 (3900)		2800 (3700)					
Haze	1500 (3200)						900 (1100)	1800	1000 (1220)	1100 (1100)
III. Ascent from Alagna to the Col d'Olen.										
	1800 (2100)		1800 (2100)		1200 (1500)	1500 (1850)				
IV. Dufour peak from the Margherita Hut.										
Cold wind			500 (1470)		950 (1350)					

The work carried out by Veil, which appears at the end of our experiments, also shows how important it is, in the case of these high figures, to determine not only the concentration of the serum, but also the concentration of the total blood according to its morphological components. Veil[1] could show that, under certain conditions, when the blood loses large amounts of water and albumen /196 simultaneously, following the puncture of large effusions, as a result of their reformation, these two values behave inversely proportional to one another. The hemoglobin content and the number of blood corpuscles increase noticeably

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[1]Veil, Deutsch, Arch. f. klin. Med. 1913,vol. 112, p.505, 1914,vol.113,p. 226.

and the albumen content of the serum decreases, and when the water loss of the

blood is quickly replaced the hemoglobin content returns practically to its nor-

mal amount but the albumen loss can be replaced only very slowly. The tests

carried out by Viel also provide information for the significance of the chlo-

rine reserves of the organism for the composition of the blood liquid. This

information relates to the proportions after chlorine losses from perspiration.

If the salt content of the diet is reduced to such an extent that no material

can be taken from the food any more for salt retention purposes, there occurs

an increase in the albumen concentration in the blood. Also, a large increase

in water with the food, resulting in a negative NaCl balance, can bring about

an increase in blood concentration. Of importance to our problem is also the

fact that, according to Veil's experiments, a negative sodium chloride balance,

resulting in an increase in the albumen concentration of the blood serum, need

not be accompained by a decrease in body weight. The water, under certain con-

ditions, can apparently be stored in the tissues and then returns again to the

blood at a negative NaCl balance so that the blood dilution which then occurs

also does not have to be accompanied by an increase in body weight.

Weber determined the hemoglobin content and the number of blood corpus-

cles. He also determined the viscosity of the serum (see the report by Weber).

For measuring the albumen concentration in the serum we used the Pulfrich re-

fractometer(Gross) recommended by Reiss[1]for blood tests. The determination of

the refractive index of the serum does not provide a precise criterion for its

albumen content. Prerequisites for a truly precise determination are that, on/197

the one hand, there is no change in the other components of the serum and, on

[1]Reiss, Ergebnisse der inn. Med. und Kinderheilkunde, Vol. 10, 1913.
This also contains all of the other literature on the refractometry of the
blood serum up to 1913.

the other hand, that no chemical bonds occur between the individual components of the serum. These prerequisites are not completely fulfilled. Reiss et al. have shown, however, in detailed tests that the fluctuations in the albumen content have by far the most significant effect on the refractive value of the serum and that the other sources of error are of such slight significance in the decrease because of change in the albumen concentration that, excluding certain exceptional cases (uremic and cholemic blood), the refractometric test can be considered as a very useful approximate method for determining the albumen content in the blood serum.

The Pulfrisch immersion refractometer used for blood investigations permitted, by using the Reisch auxiliary prism, working with only a few drops of serum. This was a very desirable feature for our tests. The instrument is calibrated in such a manner that the readings must always be made at a temperature of 17.5°C. This device, which is suitable for the most convenient adherence to a constant temperature of the water bath at average room temperature, proved to be quite inconvenient under the conditions in 1913 on the Col d'Olen. The mean laboratory temperature during our entire stay on the Col d'Olen was approximately 6° C. The carrying out of some refractometer determinations was thus frustrated because of external circumstances: the impossibility of creating sufficient amounts of warm water. Otherwise, strict attention was paid to maintaining the temperature of 17.5° constantly in the water bath and final reading was made only after the device and the serum had assumed the temperature of the water bath - when the shadow line limit did not change its position. In all cases the blood was taken from the tip of the finger and was placed in the very usefull small test tubes recommended by Reiss. The test tubes were then immediately sealed at both ends, placed in the cold and, prior to withdrawing the serum, were vigorously centrifuged in a manual centrifuge. The tests were

mostly carried out on the following day, two days later in the case of the blood

specimen taken on the top of Mount Rosa. The serum remained completely clear

at the prevailing low temperature, also in the specimens which were carried in a

knapsack from the top of Mount Rosa to the laboratory.

In the table, the figure read off of the scale (SK) is always the conver-

sion into the refractory index (n D) and the albumen content of the serum com-

puted according to the Reiss table. According to the data of Reiss[1] and Bohme[2],

the albumen content computed from these tables is always somewhat too high,   /198

about 10%. We can confirm these data for donkey blood. In comparative experi-

ments on the same person this is of no consequence. The point of departure used

was that of the serum value of the blood which was taken from each person used

in the experiment once in the morning, immediately upon awakening, while still in

bed. The other blood samples were taken immediately upon completion of the

march. It is known, and has been once more confirmed, above all by the tests

carried out by Veil (1.c), that dependable constant normal values are obtained

in all human beings only after a longer night rest, in the morning on an empty

stomach. Under these conditions, according to a large number of tests made by

Veil on healthy humans, the serum albumen value lies between 6.3 and 7.3% so

that we could content ourselves with a single determination of these normal

values for each participant in the expedition. None of us were expecially well

trained. Kestner and Schlaginweit came immediately after the end of the se-

mester term. Laquer and Weber had already been on the Col d'Olen for a long

time before the tests were begun and thus they were somewhat better prepared.

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[1] Reiss, 1.c
[2] Bohme, Deutsch Arch. f. Klin. Med. 1911, Vol. 103.

The summer of 1913 was very unfavorable for our purposes since the weather was continuously bad. Most of the trips were made under conditions of cold and haze and even on the few clear days there was such a cold wind that visible perspiration could not be achieved even after long marches with heavy packs. Occasionally, in particular on August 8th and August 13th, we had to endure extreme cold. Therefore, our tests provided information on the changes in the concentration of blood and serum during lengthy periods of muscular stress under conditions which were most unfavorable for bringing about abundant formation of perspiration.

Table 1 shows the results of our tests. The intakes and the excretions during the march were considered in determining the body weight. The rations were weighed and the discharged urine was determined by means of a measuring cylinder.

TABLE I

1. August 6. Trip to Punta Giordani (4,055 meters). Departure 8 o'clock in the morning, Return 5:30 in the afternoon. Rocks, ice, intense cold and very strong wind; continuous sensation of cold; no rest because of the cold; small intake of food.

Laquer	Sc.	n.D.	albumen %	viscosity of the serum	Hemoglo- bins	Body Weight	Body loss
Rest value	55.35	1,348,489	7.3	1.63	--	--	--
after trip	60.25	1,350,302	8.3	1.70	--	--	--
Schlagintw. Rest	--	--	6.7^{1}	1.65^{1}	--	--	--
after trip	60.90	1,350,543	8.5	1.8	--	--	--

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[1]Inserted from other analyses.

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2. August 8. Kletter trip (light). Cornu Rosso, Cornu Grosso, Punta Straling. Departure 8:30 in the morning, Return 6:30 in the afternoon. Haze, rather cold, few pauses.

	Sc.	n.D.	albumen %	viscosity of the serum	Hemoglo- bins	Body weight	Body loss
Laquer							
Rest value	58.1	1,349,507	7.9	1.8?	---	64,500	---
After trip	62.1	1,350.987	8.7	1.9	---	---	1,800
Schlagintw.							
Rest value	52.85	1,347,554	6.7	1.65	---	57,200	---
After trip unusable	hemolytic		---	1.85	---	---	1,000
Weber							
Rest value	54.25	1,348,075	7.0	1.75	89	58,200	---
After trip	62.4	1,351,098	8.8	2.0	83	---	1,100

3. Kestner immediately upon arriving at Alanga. Five-hour march. Rather warm. Heavy perspiration.

	Sc.	n.D.	albumen %	viscosity of the serum	Hemoglo- bins	Body weight	Body loss
	62.6	1,351,172	8.8	1.8	86	---	---

4. August 13. March to the Capanna Margherita. Cold, haze, finally strong wind and severe cold. Two longer breaks en route; heavy packs.

	Sc.	n.D.	albumen %	viscosity of the serum	Hemoglo- bins	Body weight	Body loss
Kestner							
Before trip	---	---	---	---	---	85,500	---
After trip	64.20	1,351,762	9.2	1.9	---	---	3,450
Laquer							
Before trip	---	---	7.3[1]u.7.9[1]	1.63[1]	---	64,600	---
After trip	64.50	1,351,870	9.2	2.0	86	---	3,150
Schlagintw.							
Before trip	---	---	---	---	86	57,100	---
After trip unusable	hemolytic		---	---	83	---	2,300

The blood samples from a second ascent to the Capanna Margherita un- fortunately could no longer be tested because of outside reasons (premature closing of the laboratory).

The table shows that the refractometric albumen values of the serum lie

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[1]Inserted from other analyses.

(also in mountain areas at rest) within the range of a large number of normal increased values by Veil (6.3-7.3%). Only for Laquer do the values lie somewhat higher and the other two values lie in the upper half of the normal range, whereas in the case of the rest values given by Bohme[1] and Reiss they lie on the lowest limits of the standard values or even somewhat below that. Since Veil's tests were carried out on the largest number of healthy persons and under conditions which fully correspond to those we faced, a comparison with his figures is the most appropriate and shows that even under the conditions of mountains, the refractometrically measured concentration of the serum does not change when compared with under flat land conditions. The refractometer value and the viscosity of the serum increase normally after the marches. The increase in albumen content corresponds fully to the values found by Bohme for work of short duration by means of an ergostat or dumbbells. (9.16%,8.76%, 9.05%,8.90% albumen immediately upon termination of the muscular activity). In the case of these short-lived muscular activities the albumen content of the serum increases rapidly and then remains unchanged at a certain level which does not depend upon the amount of total work but essentially upon the respective work at the moment and decreases rapidly once more after the work is terminated. The water loss of the blood determined from the increase in concentration is considerably smaller than the decrease in body weight. The greatest increase in concentration was found by Weber on August 8 to be from 7.0 to 8.8. The weight of the body is 58.2 kilograms. If we calculate the blood to be 5.5% of the body weight and the serum to be 60% of the blood then we obtain 1965 ccm

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[1]Bohme, Deutsch. Arch. f. klin. Med. 1911, Vol. 103.

of serum and the increase in albumen content from 7.0 to 8.8 would correspond

to a decrease by 403 ccm. A weight decrease of 1,100 grams is observed. In <u>/201</u>

the other tests the water losses from the serum which are to be calculated lie

between 200 and 300 ccm, the weight losses are much greater, as much as ten

times greater. This corresponds with our results which are referred to further

on. According to these results the actual supply of the body occurs from the

water reservoirs of the muscles.

In Bohme's tests the rapid increase a few minutes after beginning of work

and the remaining at constant of the values at constant work, already indicates

that the serum concentration is not caused by the loss of water through the

skin and the lungs but rather through another distribution of the water in the

organism. This view is completely verified by our tests which show that, even

after hours of walking (up to ten hours) with a heavy pack, no greater values

can be obtained than were observed by Bohme after work which lasted twenty

minutes at the most.

Still other factors, however, come into the picture. Bohme observed an

increase in the hemoglobin content in the total blood simultaneously with an in-

crease in the albumen content in the serum. However, the increase in hemoglo-

bin often did not completely correspond to the increase in the albumen in the

serum. Bohme explains this by an unequal distribution of erythrocytes in

various capillary regions. We also found the above-explained but nevertheless

insignificant decrease in hemoglobin content with an increase in the albumen

content in the serum. The findings were so regular (compare Weber's report)

that an irregularity in the erythrocyte distribution could not be held respon-

sible for it. Under the effect of muscular activity and water loss through

perspiration we come upon an increase in the total liquid (measured on the erythrocyte content) with a simultaneous increase in the albumen concentration of the serum. This finding appears contradictory since it should be expected that either the hemoglobin and albumen content would increase to the same extent when the blood loses more water than flows in from the tissues or else, on the other hand, both values would decrease when the reserve from the tissues exceeds the loss. Now we know from the tests made by Magnus[1] and Hosslin[2] that /202 albumen also accompaines the liquid exchange between the blood and the tissues and that albumen also enters the blood from the tissue liquid with the infusion of a hypertonic NaCl solution with the water. The proportions can therefore be introduced in such a manner that the water loss from the skin and lungs can be covered by an inflow from the tissue and that in this way a liquid containing albumen flows in while the blood only gives up water or salt solution through the lungs and the skin. Thus an adjustment to a greater albumen concentration can take place with a simultaneous increase in the total liquid. An example of a reverse behavior during continuous albumen loss from the serum is given by the observation made by Veil[3] which is referred to in the beginning of the paper. Observations concerning marches during very intense heat and very great water loss through perspiration are lacking to complete our tests. In 1913, unfortunately, we had no opportunity to carry out observations of this type. In order to explain the changing conditions in the same person tested it would also be necessary to compare work of short duration and work of long duration,

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[1] Magnus, Arch. fur exper. Path. u. Pharmak. Vol. 44.
[2] H. v. Hosslin, Deutsch. Arch. f. klin. Med. 1907, Vol 74, P. 575.
[3] Compare Veil and Spiro, Munch. Med. Wochenschr. 1918. P. 1119.

and work during cold weather and work during hot weather. In the meantime, a part of these tests has been carried out by one of us in Hamburg and A. Eckert presents a report on this in this journal. Above all, we must bear in mind (much more than previously as regards both the water exchange and the exchange between the blood and tissue) that complicated controls exist which perhaps depend upon the nervous system and by means of which in the case of manual labor, perspiration or kidney activity, a stream of water flows in or out of the blood even before the need arises. In this way we can easily imagine over-compensations as are observed in the area of heat control and breathing control during muscular activity. Cronheim, Kreglinger, Tobler and Weber have inter- /203 preted the feeling of thirst after heavy perspiration to be one of these complicated types of controls. As is shown by the above-mentioned behavior of the body weight, water which is taken with food weak in salt is not deposited, it reaches into the blood but is not able to fill up the water reserves because of the lack of salt and is excreted by the kidneys. Refractometric analyses were not made at that time. It was concluded from the decrease in hemoglobin that there was a general dilution of the blood and we were forced to the conclusion that the water deficiency in the blood could not be the reason for the sensation of thirst but that the cause was a distant action. Refractometric analyses during great losses of perspiration and great thirst were also lacking for this problem. In this case, however, we could make supplementary use of the viscosity-measuring tests made by Weber (compare his last paper). Weber climbed up to the Margherita hut on August 22nd and returned to the laboratory on the 23rd and lived during this time without chlorine. The loss in weight (compare the previous table) amounted to 2,600 grams and up to the following morning the weight sank by another 200 grams and thus it was impossible to

replenish the water reserves. The following data was obtained:

	Blood viscosity	Serum viscosity	Hemoglobin
August 21 morning	5.90	1.70	82
August 22 after arrival	6.73	2.00	87
three hours later	6.10	----	84
August 23 morning	6.40	1.90	86
Noon	6.00	1.80	87
Evening on the Col d'Olen	5.80	1.70	87
August 24 morning	5.38	1.70	81

As a result of the similarity between the refractometric values and the viscosity values, both of which were caused by the albumen content of the serum, we could conclude from these values that in the case of food weak in salt, not only does the serum become concentrated, but the blood also becomes richer in blood corpuscles and the increase in concentration does not quickly diminish after manual labor but remains for a longer period of time. The regulating capacity of the blood becomes defective when there is a deficiency of sodium chloride. The blood and the fluidity of the blood are therefore actually more concentrated than usual and the assumption of a stimulation of the sensation /204 of thirst from the water reserves becomes unnecessary.

The findings on human beings should be completed and expanded by means of tests on animals. In order to create the most comparable conditions, animals that perspire profusely should be selected. The small Sardinian pygmy donkeys appeared to be the best and relatively cheapest animals for this purpose. A carotid fistula was applied to the animals, also in regard to other planned tests   (compare the report by Schlaginweit). This fistula made possible the extraction on several successive days of an abundant amount of blood for all planned tests without harming the animals. According to tests by Bohme[1] and

[1]See next page.

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Schwenker[2], capillary blood and arterial blood is of the same value for the re-

fractometric analysis. The greater amount of blood always made it possible to

undertake a freezing-point analysis in the serum with the Beckmann device and

also to carry out a Cl analysis and an albumen analysis (Kestner).

Five ccm of the serum was diluted with water, mixed with a drop of acetic

acid and boiled. It was always possible to obtain a clear quick-draining fil-

trate. The albumen coagulum was collected on a weighed filter, was rinsed free

of chlorine first by hot water and then by cold water, treated with alcohol and

ether, dried in a drying rack to weight constancy and then weighed. The chlo-

rine was analyzed in the filtrate according to the Volhard method. According

to other experiences[3] it is not necessary to incinerate in order to analyze

the chlorine in the serum.

Actual rest and empty stomach values of the serum could not be obtained

here. The animals, indeed, avoided as much as possible any superfluous move-

ment, most of the time stood in the stalls, and were not therefore in a state

of complete muscular inactivity. Therefore, blood was always extracted for

test purposes immediately before and after every march. In the beginning the

animals were led upward and downward over steep roads, occasionally they were

even loaded down (donkey 1). Later it proved to be more appropriate to drive

them in a simple manner. The advantage to this was that they could continuously

be kept at a fast pace (shorter trot), but this was extremely tiring for the _/205_

persons in charge. The cool temperature of August 1913 proved to be very detri-

mental in this case too. The animals were for the most part wet and it was not

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[1]Bohme, 1. c.
[2]Schwenker, In-Diss. Kiel 1911.
[3]O. Cohnheim, Zeitschr. f. phys. Chem. 1913, Vol. 84, P. 451.

possible to obtain visible perspiration and the weight losses were also less

than we had expected. In the case of donkey 1 the weight loss amounted to less

then one kilogram, even though the animal was clearly exhausted. The results

are given in the following table. The viscosity analyses are from Weber's sub-

sequent report. The hemoglobin values were once more determined by means of

the Autenrieth-Konigsberger colorimeter and converted to the Sahli hemometer.

The refractometric analyses were carried out as above.

	Hemoglobin Sahli		Refractometer Scale Division		Refractometer Refracting index		Refractometer Albumen %	
	Rest	Work	Rest	Work	Rest	Work	Rest	Work
Donkey I	58	54	55.15	54.50	1,348,415	1,348,170	7.2	7.1
Donkey II	60	70	51.20	52.90	1,346,944	1,347,573	6.4	6.7
Donkey III	50	48	58.20	55.45	1,349,544	1,348,516	7.9	7.3
Donkey IV	--	--	57.65	58.00	1,349,335	1,349,470	7.8	7.8

	Albumen weighed %		Viscosity Serum		Freezing Point Δ		Cl Na %		Viscosity Blood	
	Rest	Work	Rest	Work	Rest	Work	Rest	Work	Rest	Work
Donkey I	6.60	6.58	1.80 1.75	1.75	-0.598	-0.575	0.58	0.59	4.15	3.92
Donkey II	5.76	6.24	1.63	1.68	-0.605	-0.543	0.54	0.54	3.90	4.43
Donkey III	7.32	6.93	1.90	1.80	-0.555	-0.533	0.60	0.70	3.75	3.50
Donkey IV	----	----	1.90	1.90	-0.535	-0.520	0.54	0.54	----	----

It was then shown, and this is important from a methodology viewpoint,

that the refraction, viscosity and the directly-analyzed albumen content al-

ways followed in a parallel manner. The albumen values which have been com-

puted from the table according to the refractometer figures were, as has al-

ready been mentioned earlier, absolutely too high and this was meaningless for

our problem. On the other hand, a pattern is obtained here which is not as un-

iform as in the case of tests on humans. In two cases (1 and 3) the

concentration of the serum and the concentration of the hemoglobin were simi-
lar. In one case (2) both increased and in one case (4) where the hemoglobin
was not determined, the concentration remained the same after particularly
strenuous exertion. The smaller freezing-point decrease of the serum after
muscular activity is constant in the case of all four animals, whereas the sod-
ium chloride content was unchanged in three cases and in one case dropped con-
siderably. The smallness of the differences can be the result of the fact that
we did not have any actual rest values, partly we also did not have any values
in the various intensities of movement. Nevertheless, the exertion in donkeys
2 and 3, which reacted in opposite manner with respect to the serum value and
the hemoglobin, was consistent to a certain degree. Thus, excluding the metho-
dical control, we can then only make one conclusion, that muscular exertion and
its after effects also greatly effect the composition of the arterial blood.
The hemoglobin and refractometer values of Veil[1] also provide a completely
irregular pattern from the phenomena concerning water and salt exchange. Prob-
ably, as so often occurs, oppositely-directed processes take place.

It was therefore much more important to also investigate the tissue and
not just the blood that unites the tissue. We could use donkeys for this too.
The behavior of the tissue during intravenous intake of hypotonic and hypertonic
sodium chloride solutions (therefore water and salt) was studied in the labora-
tory by Engels[2], Wahlgreen[3] and Padtberg[4]. They found that the water which was
infused into dogs found its way into all of the organs, but that the primary

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[1]Veil, 1, c.
[2]W. Engels, Archiv f. exper. Path. u. Pharmak. 1904, Vol. 51, P. 346.
[3]V. Wahlgreen, ibid. 1909, Vol. 61, P. 97.
[4]J. H. Padtberg, ibif. 1910, Vol. 63. P. 60.

water depot is the muscles. The necessary water is taken from the muscles in the case of the intake of strong salt solutions. The primary chlorine depot, in which infused sodium chloride collects, is, on the other hand, the skin and the chlorine is given out from the skin also in the case of food weak in chlorine. Tobler[1] brought about profuse diarrhea in young growing dogs with magnesium sulphate until the animals died from the water loss and he then determined the loss of water, fat, solid matter and ashes in the individual organs. /207 The principal loss in water was borne by the skin and musculature which were not acted upon separately. The salt loss was also, however, large and in relation to the water loss. Based on the dog experiments and clinical observation, Tobler differentiates three types of water loss in the body. First of all, the body was able to dispose of water through perspiration or in some other way without affecting the salt content and composition (concentration water). The second part is composed of the amount of water which cannot be present without a certain amount of salt and which, as a result of this, cannot be restored without at the same time adding salt. Tobler refers to this as reduction water. These two portions form the superfluous (unnecessary) water, i.e. the content of the water depots. This is opposed by the third portion, the destruction water, which forms a part of the tissue and cannot leave the organism without causing severe damage to it. If destruction water is lost there is also always a loss in tissue nitrogen and tissue ashes. Cohnheim, Kregliner, Tobler and Weber agreed with this classification. The water losses during perspiration which we observed naturally only concern the first two types of water. However,

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[1]L. Tobler, ibid. 1910, Vol. 62, P. 431.

it appears possible to more accurately determine from their amounts the portion of the concentration water and the reduction water in human beings. Their figures indicate that in the case of excrements which are weak in salt the weight losses through perspiration can never completely be compensated. But a slow increase does occur and this increase must be related to the water that can be replaced even without salt, i.e. the concentration water within the meaning of Tobler. In three cases no increase occurred whatsoever, eight times the increase amounted to 50, 300, 550, 650, 900, 1,950 and 2,050 grams. The concentration water would therefore fluctuate between these amounts.

In the case of the experiments on the small donkeys we proceeded thus: /208

Two donkeys were killed after the most complete quiet by cutting their throats. Three were killed after they were brought to perspire in the described manner. The abdominal cavity was opened immediately after death, an arteria iliaca was prepared, a tubule was tied up into it, the vena iliaca was cut through and the leg was thrilled through from the artery out with oxygen from an oxygen tank. The blood had to be removed since it would have affected the results by its high dry substance and its high chlorine content. Thrilling through with fluids would have caused unpredictable sources of error. Practically all of the blood was removed in a few minutes with oxygen. We were subsequently quite elated over this. The minimum chlorine content of the muscle also indicated that the blood was removed for all practical purposes. Then two pieces taken from the upper thigh muscles and from the skin were immediately placed in sealed vessels and weighed and then the dry substance and the chlorine were determined. The dry substance was determined while the pieces were dried in a drying rack after initial addition of alcohol up to the weight constancy. In order to obtain the chlorine content, the pieces were well

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cooked after a bit of saltpeter was added and the chlorine was determined in the filtrate according to the Volhard method. After incineration the residue proved to be free of chlorine. The determinations of the dry substance of a donkey were lost. We also took samples of the subcutaneous cell tissue but we did not obtain any usable values. The subcutaneous cell tissue is very poorly developed in donkeys.

The results showed the following composition. The chlorine calculated for sodium chloride. Two donkeys which had the greatest possible quiet and three donkeys which were agitated as much as possible and forced to perspire before they died, were compared. But, all of the analyses were not carried out because the laboratory closed prematurely.

Donkey 1. At rest

1.7290 g muscle gave traces of NaCl			--
1.2720 " " " 0.2656 g dry substance			20.88%
3.0072 " skin " 12.9 mg sodium chloride			0.43"
2.2854 " " " 0.5850 g dry substance			25.50"

Donkey 5. At rest

0.3850 g muscle gave 0.0788 g dry substance	20.47%
0.7564 " skin " 0.2366 " " "	30.10"

Donkey 2. Active

2.2319 g muscle " 1.75 mg NaCl	0.08%
0.6192 " " " 0.1610 g dry substance	26.16"
3.3931 " skin " 16.38 mg NaCl	0.48"
0.3766 " " " 0.1231 g dry substance	23.97"

Donkey 3. Active

0.6128 g muscle gave 0.1469 g dry substance	23.97%

Donkey 4. Active

0.9948 g muscle gave 0.2165 g dry substance	21.80%
0.4899 " skin " 0.1360 g " "	27.76"

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In 100 g of organic substance there is:

Dry substance Muscle		Sodium chloride Muscle		Dry substance Skin		Sodium chloride Skin	
Rest	Active	Rest	Active	Rest	Active	Rest	Active
20.88	26.16	trace	0.08	25.50	23.97	0.43	0.48
20.47	21.80	---	---	30.10	32.70	---	---

The figures show that the muscle gives up water during activity and perspiration. Engels and Wahlgreen, who recognized that the muscle is a water depot, determined the intake of water in the muscle and the secretion of water from the muscle when they intravenously applied hypotonic and a hypertonic salt solutions into the dogs. Tobler also carried out experiments on water losses in the case of diarrhea which resulted in death. It can be concluded from our figures that the muscles are the water reservoirs also in the case of physiological perspiration and that the body restores its water losses from the muscles. The chlorine content of the muscle is too slight to be able to attach any importance to its displacement.

The pattern is not uniform in the case of the skin. Apparently the skin can give up water. The skin can also be saturated by the perspiration when the sweat glands in the skin secrete; then the water content and the salt content increase. The conditions are complex in the case of perspiring animals.

RESULTS

Water and salt are only temporarily taken from the blood in the case of manual labor and the secretion of perspiration provoked by the labor, and there comes about a brisk exchange between the blood and the tissue.

1. The total blood becomes richer in plasma, poorer in blood corpuscles

and therefore dilutes.

2. The plasma becomes richer in albumen and therefore becomes concentrated. The salt content remains rather much the same.

3. After great secretions of water through perspiration, water can be fully replaced only with the corresponding salt intake.

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